RESEARCH NOTE 84-16

MAINTENANCE PERFORMANCE SYSTEM (ORGANIZATIONAL)
THE EFFECT OF JOB EXPOSURE ON MAINTENANCE PROFICIENCY: TEST RESULTS FOR THE AUTOMOTIVE TANK MECHANIC (63N)

V. Alan Spiker
Anacapa Sciences, Inc.

Michael Drillings and Melissa Berkowitz,
Contracting Officer's Representatives

Submitted by

Robert J. Seidel, Chief
TRAINING AND SIMULATION TECHNICAL AREA

and

Harold F. O'Neil, Jr., Director
TRAINING RESEARCH LABORATORY

U. S. Army
Research Institute for the Behavioral and Social Sciences

January 1984

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: Research Note 84-16	2. GOVT ACCESSION NO.: AD-A138 444
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): Maintenance Performance System (Organizational) The Effect of Job Exposure on Maintenance Proficiency: Test Results for the Automotive Tank Mechanic (63N)	5. TYPE OF REPORT & PERIOD COVERED: Contractor Report
	6. PERFORMING ORG. REPORT NUMBER: TR465-27
7. AUTHOR(s): V. Alan Spiker	8. CONTRACT OR GRANT NUMBER(s): MDA 903-81-C-0032
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Anacapa Sciences, Inc. Drawer Q Santa Barbara, CA 93102	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 2Q263743A794
11. CONTROLLING OFFICE NAME AND ADDRESS: US Army Research Institute for the Behavioral & Social Sciences 5001 Eisenhower Ave. Alexandria, VA 22333	12. REPORT DATE: January 1984
	13. NUMBER OF PAGES: 53
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report): UNCLASSIFIED
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

This project was monitored technically by Dr. Michael Drillings and Dr. Melissa Berkowitz

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Maintenance, Management Information System, Maintenance Training

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The purpose of this effort is to develop the Maintenance Performance System-Organizational (MPS-O) which is an integrated system for measuring maintenance performance, diagnosing performance problems, taking corrective actions, and providing training. This report describes a study to determine the relationship between frequency of maintenance task performance--job exposures--and corrective maintenance skill levels of automotive tank mechanics. Conclusions from this research will help establish the validity of using data on job exposure frequency to identify and correct deficiencies in individual repair skill.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

TECHNICAL SUMMARY

PROBLEM

The Army emphasizes on-the-job training (OJT) as a way to develop the proficiency of battalion and company maintenance personnel. However, OJT programs seldom include ways to measure mechanic proficiency. Measuring OJT is not done because accurate measures are difficult to administer. Easy-to-administer measures are suspect in terms of validity and reliability. Therefore, without satisfactory proficiency measures, skill deficiencies cannot be identified for correction.

One component of the Maintenance Performance System (Organizational), MPS(O)), proposes to measure the proficiency of individual mechanics by monitoring their job exposure. Job exposure measurement assumes that a mechanic's proficiency is increased through the practice gained in repeated exposures to the same job. However, the relationship between proficiency and job exposure has not been tested empirically. The research reported here was conducted to assess this relationship.

APPROACH

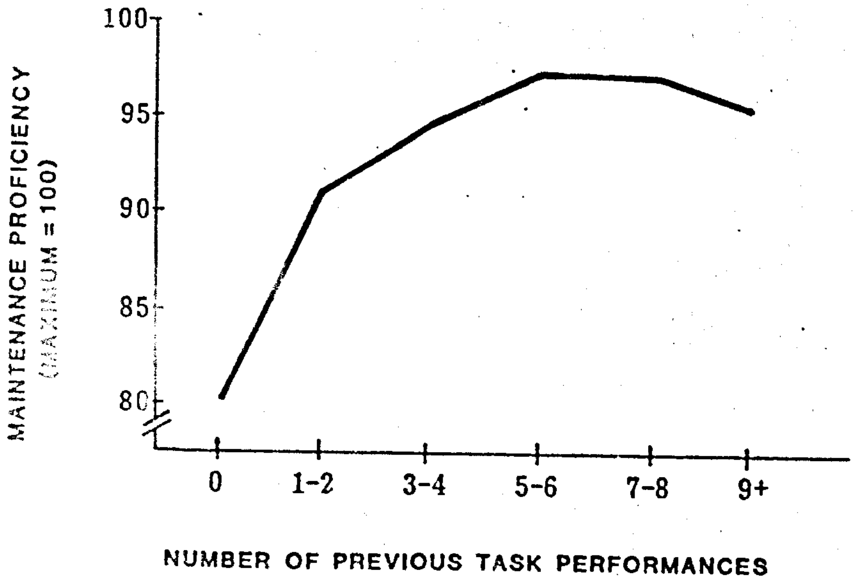
The relationship between job exposure and maintenance proficiency (i.e., skill level) was examined in a controlled experimental study. A total of 70 tank automotive mechanics (most with MOS 63N) were individually tested on two M60A1 tank repair tasks--starter installation and generator installation. Testing was conducted by an Army battalion maintenance technician with 20 years of experience who had retired recently. The mechanics tested had performed the tasks either 0, 1, 2, 3, 4, 5, 6, 7, 8, or 9 or more times prior to testing. Maintenance proficiency measures consisted of: use of the technical manual, adherence to the prescribed repair sequence, tool selection, tool use, checks of repair quality, and repair time.

RESULTS

The study produced the following results:

- Performance frequency was strongly related to maintenance proficiency, accounting for one-half the total variation in the test data.
- Similar functional relationships were found between performance frequency and six different measures of maintenance work, suggesting that performance frequency was strongly related to all components of maintenance proficiency.
- The function relating maintenance proficiency to performance frequency was similar for two different maintenance tasks, suggesting that the observed function is reliable and valid.

- Overall, maintenance proficiency increased with additional task performances, peaked between five and six performances, and declined slightly beyond six performances as shown in the figure below.



Relationship of maintenance proficiency to performance frequency.

CONCLUSIONS

- Performance frequency is an accurate and useful indicator of maintenance proficiency. It is strongly related to six different dimensions of maintenance proficiency--quality checks, adherence to procedures, repair time, information use, tool selection, and tool use.

- The job exposure index, derived from records of performance frequency, should be retained in the MPS(O) for assessing skill growth, providing individual skill profiles, and identifying skill development needs.

- Comments made by subjects about the testing suggested that elements of the controlled testing environment could be effectively transferred as components of an OJT program.

- Further research is needed to determine the reasons for the decline in proficiency displayed consistently by the mechanics with greatest job exposure.

BEST AVAILABLE COPY

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

This report concerns a unique way of measuring job skill. Whereas formal hands-on tests of a mechanic's repair performance are widely acknowledged to be accurate and valid reflections of skill, they consume too many resources to be efficiently applied on a large scale. As part of its long-term effort to improve company-level maintenance, the Maintenance Performance Systems (Organizational) (MPS(O)) is planning to use a simple, easy-to-collect substitute for the formal, hands-on skill test--the mechanic's number of previous job experiences on a task. The search for an economical, objective skill measure was prompted by the Army's need to guide on-the-job training (OJT) programs at the company and battalion level. Monitoring skill growth and managing OJT are two of the primary goals of the MPS(O).

A study was conducted to determine if job exposure--defined as the number of times a task has been performed--is, in fact, an appropriate measure of skill. Although job exposure (JE) is hypothesized to reflect repair skill, is it a valid measure? If it is not, then it should not be used in the MPS(O). The present study asked whether job exposure was a valid index of skill in the context of four separate, but related, questions.

- How closely related are JE and repair skill?
- What is the quantitative relationship between JE and repair skill?
- Is there a reliable relationship between JE and repair skill that can be generalized to different maintenance tasks?
- Does job exposure reflect a single dimension, or does it reflect most of the dimensions of repair skill--quality, repair time, tool selection, use of tools, use of information, and adherence to procedures?

Although it seems reasonable to assume that more JEs lead to better repair skill, the two are not necessarily related. Job experience may be accrued too haphazardly, individuals may vary too much in their rate of skill acquisition, and poor repair habits may get ingrained too quickly and cloud the real relationship between JE and skill. Since there was little available scientific evidence from which to draw firm conclusions, the work reported here was designed to fill this gap. Before describing the study's methodology and results, the role of JE in the MPS(O) and results of recently completed research directly relevant to this issue are discussed below.

BACKGROUND

According to the OJT model developed for the MPS(O),[1] the company-level training manager implements OJT in three steps: He determines the maintenance proficiency level for each mechanic, he identifies those repair tasks that each man has not yet mastered, and then he designs an individualized training program to correct those skill deficiencies. The key step in the OJT process is determining each mechanic's current skill level, i.e., how **well** can a mechanic perform each repair task?

Job Exposure and the MPS(O)

In the current version of the MPS(O), JE is employed as an indicator of repair skill. For a given task, a mechanic with 2 JEs is considered to be more skilled than a mechanic with 1 JE, but less skilled than a mechanic with 3 JEs. Every time a mechanic performs a task, the system increases his JE index by one. The MPS(O) provides regular listings of each mechanic's JE count on every repair task. By reviewing the list, the mechanic's supervisor can determine those tasks in need of OJT or JE. Table 1 illustrates the link between JE and skill development recommendations for a few 63N corrective maintenance tasks. The tasks are listed in descending order of their need for OJT or JE.

Previous Research

The assumption that JE can be used to substitute for a direct measure of repair skill has been challenged in a recent study by the Army Research Institute.[2]

---

[1]Simpson, H. K. **Maintenance performance systems (organizational). Supervisor's OJT guide.** Santa Barbara, CA: Anacapa Sciences, Inc. (Technical Report 465-21), June 1982.

[2]Kern, R. P., & Hayes, J. F. **Improving maintenance performance: Application of research to operational problems.** Alexandria, Virginia: U.S. Army Research Institute for the Behavioral Sciences, February 1982.

TABLE 1

EXAMPLE OF CORRESPONDENCE BETWEEN JOB EXPOSURE AND NEED FOR OJT FOR A 63N TANK MECHANIC

TYPICAL REPAIR TASKS	JOB EXPOSURE	INTERPRETATION
1. Replace Starter	0	Needs OJT or JE
2. Adjust Servo Bands	0	Needs OJT or JE
3. Replace Generator	1	Needs OJT or JE
4. Replace Master or Slave Cylinder	1	Needs OJT or JE
5. Replace Shock Absorber	2	May need supervision
6. Repair Wiring	3	May need supervision
7. Bleed Brake Lines	4	May need supervision
8. Replace Parking Brake Cable	6	May need supervision
9. Remove Powerpack	7	Achieved Mastery
10. Ground Hop Powerpack	7	Achieved Mastery
11. Install Powerpack	7	Achieved Mastery
12. Remove Back Deck	7	Achieved Mastery

Trained technicians went into company motor pools to observe tank mechanics perform corrective maintenance tasks under operational conditions. Detailed records were kept on the number, and type, of maintenance errors committed on the job. Critical errors were found to be committed frequently in most maintenance jobs, and experienced mechanics were found to make as many errors as beginning mechanics. The researchers concluded that a mechanic does **not** become more proficient with practice. They contended that mechanics typically received little feedback on the quality of their work, resulting in the learning and retention of bad repair habits. As an assessment of repair performance, the study provided valuable insights into the problems faced by mechanics in operational conditions. But because repairs were observed under poorly controlled conditions, and the level of difficulty of the repairs varied, it is not possible to determine the relationship between job exposure and skill levels from these data.

ANTICIPATED OUTCOMES OF THE CURRENT STUDY

Four possible outcomes for the quantitative relationship between JE and repair skill were anticipated prior to the current study. Each is described below:

1. **JE is unrelated to repair skill.** Figure 1A shows repair skill to be a flat function of JE. This function is consistent with the results of the study discussed above, and would invalidate the use of JE in the MPS(O).

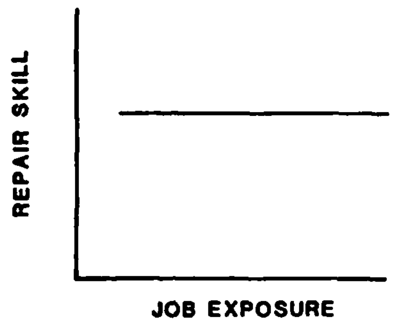


Figure 1A.

2. **Repair skill first increases, then levels off.** The relationship portrayed in Figure 1B shows that repair skill reaches a plateau after a finite number of JEs and does not increase.

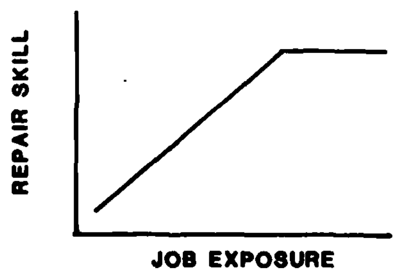


Figure 1B.

3. **Repair skill increases indefinitely with JE.** Figure 1C shows the case in which a mechanic's repair skill improves continuously with more JEs. This relationship implies that even highly experienced mechanics could benefit from further JE.

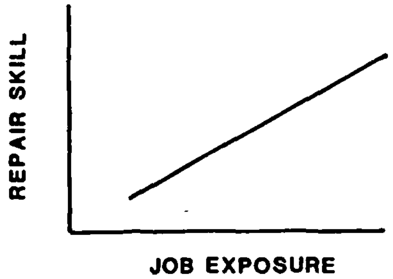


Figure 1C.

4. **Repair skill first increases, then decreases slightly as a function of JE.** Figure 1D depicts this relationship between JE and repair skill. A decline in skill among the more experienced mechanics would be consistent with anecdotal reports that, over time, these men become careless and cynical, lose motivation, and let their skills atrophy.

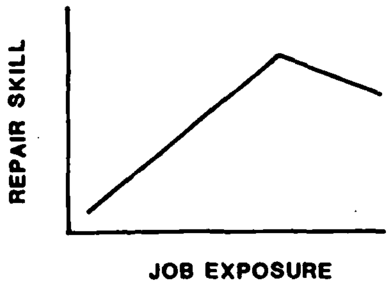


Figure 1D.

METHOD

STUDY DESIGN

The relationship between JE and repair skill was examined using a between-subjects type of experimental design. Subjects were mechanics who routinely performed corrective maintenance on the M60A1 tank engine; most had a 63N MOS. To increase study generalizability, two different tank repair tasks were employed--installing a starter, and installing a generator.

Only about 70 mechanics were available for testing, which restricted the number of subjects per JE category and the range of JE categories that could be included. A study design was therefore adopted that, within the practical constraints imposed by field testing, maximized the sample's statistical reliability over the most critical range of JEs. A minimum of five subjects was drawn from each of ten categories of JE; 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9 or more. The minimum sample size was doubled in the two outside JE categories, 0, and 9 or more (9+), for the following statistical reasons:

- To compensate for the limited numbers of subjects in the experimental design, it was intended that the data for subjects in adjacent JE categories be combined in the statistical analysis. Since subjects in the two outside JE categories represented a different statistical population from those in the middle JE categories, their data could not be pooled with those from another category. These two JE categories therefore required more subjects to stand alone.
- There are more mechanics having either none, or many, JEs than there are having moderate numbers of JEs. Increasing the sample in the two outside JE categories reflected the JE of the actual population of mechanics.

A total of 68 starter, and 67 generator, repair proficiency tests were administered to 70 different subjects distributed across the 10 JE categories as shown in Table 2. For subjects taking both tests, test order was randomly varied across subjects to control for sequence effects. Subjects who had different exposures to starter and generator repairs appeared in different JE categories in the two tests. For example, a mechanic who had performed two starter and four generator repairs would be placed in JE Categories 2 and 4, respectively, for the starter installation and generator installation tests.

TABLE 2

NUMBER OF MECHANICS TESTED IN EACH JOB EXPOSURE CATEGORY

JOB EXPOSURE CATEGORY	REPAIR TEST STARTER TEST	GENERATOR TEST	TOTAL
0	16	12	28
1	5	6	11
2	5	5	10
3	5	6	11
4	5	5	10
5	5	5	10
6	5	5	10
7	5	6	11
8	5	7	12
9 or more	12	10	22
Total	68	67	135

TESTING CONDITIONS

Testing was conducted between 26 July and 19 October 1982 in the 2/34 Battalion welding shop at Fort Carson, Colorado. The shop was off limits to maintenance personnel during testing periods, with the shop doors always closed to provide subjects with a non-distracting test environment. Overhead illumination was good.

Both tests were conducted on an M60A1 engine that had been removed from the tank hull and placed on an engine stand. Prior to the study, the engine and all test replacement parts were steam-cleaned. To ensure comparable test conditions across subjects, all tools, parts, and technical manuals (TMs) were placed in fixed locations on a plastic-coated display board situated near the engine. Use of the display board eliminated the need for men to rummage through tool boxes or find damaged TMs and parts, activities that would contaminate the scoring of the test components.

JOB EXPOSURE INDEX

The JE level of each subject was defined via interview. Upon arriving at the test site, a subject was asked to indicate the number of times he had replaced a tank starter, and the number of times he had replaced a tank generator, since completing formal school training. Subjects were required to give their JE as a single number, not a range of numbers. Subjects were placed in the JE category that corresponded to their self-reported JE.

TEST INSTRUMENT

Starter installation and generator installation were each broken down into a sequence of discrete, observable performance steps that could be objectively scored by an experienced maintenance technician. Based on input from Fort Carson maintenance experts, and an analysis of the prescribed steps in TM 9-2350-257-20-1-3, preliminary versions of each test instrument were field-tested and revised. The final versions of the instruments are presented in Appendix A (starter) and Appendix B (generator). Because time and resources were limited, the removal steps and the final "ground-hop" check-out for each task were not included in the test. A complete description of all parts, tools, manuals, and scoring rules formed part of each test instrument.

Maximum score on each proficiency test was 100. The total score on each test was the sum of scores on six subtests as shown in Table 3. The rationale behind the scoring system is described below.

Knowledge of Technical Manual

The test began with 10 questions, worth 1 point each, that covered information contained in the TM provided for that repair. Subjects were encouraged, though not required, to use the TM to answer the questions. Since most subjects elected to use the TM, these questions were designed to test the man's ability to use the TM rather than his memory of task-related facts. Performance was not timed.

TABLE 3

MAXIMUM NUMBER OF POINTS AWARDED IN EACH SUBTEST

GENERAL CATEGORY	SUBTEST	REPAIR TEST STARTER	REPAIR TEST GENERATOR
Accuracy	Knowledge of TM	10	10
Accuracy	Following Sequence	31	30
Accuracy	Selecting Correct Tool	11	12
Accuracy	Using Tool Correctly	11	12
Accuracy	Checking Quality (Working to Spec.)	12	3
Time	Time to Finish (min):		
	If under 40 award:	25 (use only one)	33 (use only one)
	If between 41-48, award:	18	24
	If between 49-55, award:	11	15
	If between 56-60, award:	4	6
	If over 60, award:	0	0
Proficiency	Total Possible	100	100

Following Correct Step Sequence

The hands-on component of the test consisted of a series of discrete, objective performance steps--31 for the starter test and 30 for the generator test. Subjects were awarded a point for every step performed in the correct sequence. In the case where a group of steps was either left out or performed out of sequence, points were lost only in the steps directly affected by the sequence violations.

Selection and Use of Tools

Eleven steps in the starter test and 12 in the generator test involved tools. For these steps, the test administrator could award up to two additional points if the mechanic (1) selected the correct tool and, (2) used that tool correctly. For example, consider TM Step Number 18 of the Generator test, "tighten screws using 9/16 in. socket." The subject would lose one point if he had selected the wrong tool, such as a 9/16" open end wrench. Another point would be lost if he used the wrench as a crowbar, rather than to tighten a nut.

Checking Quality of Key Steps (Working to Specifications)

Some steps were especially critical to the success of the repair, and their performance had to be checked against a known standard. Twelve steps in the starter test and three in the generator test required an explicit check for quality. In some of these steps, the subject had to work to a certain specification, such as by tightening a locknut to a given torque. In others, he had to visually inspect his work, as when ensuring that a terminal nut was clean.

Time

Time to complete the performance steps was recorded to the nearest minute. A total proficiency score was derived by converting time in minutes into bonus points according to the conversion rule given in the lower part of Table 3. These bonus points were then added to the other criteria scores to yield the total proficiency score. The upper and lower time cutoffs, 60 min. and 40 min., were based on what Fort Carson maintenance experts considered to represent slow and fast installation times, respectively.

TEST PROCEDURE

The test site was secured and the test materials assembled during the week before data collection started. The test administrator, a recently retired battalion maintenance specialist with over 20 years of repair experience, supervised the installation of the test engine and readied it for testing. The authors and the test administrator met often during the preparatory week to discuss principles of good test administration, the importance of tight control over test conditions, and the rules for providing feedback to subjects. The characteristics of these sessions were summarized in an earlier report.[1] During the latter part of the week, the rules for scoring each performance step were finalized and practice tests were given.

Subjects were drawn from four armored battalions and scheduled a week in advance. Each subject was tested individually in the following way: Upon arriving at the test site, the subject was asked to give his name, primary MOS, paygrade, and social security number. Next, he read a privacy act release form and was told that his participation in the study was strictly voluntary (only one mechanic refused to participate). Reading from the script shown in Appendix C, the test administrator asked the subject for the number of JEs he had on each repair task, as well as an estimate of the number of days since he had last performed each task. The subject was also asked for the name of his AIT school and when he graduated. Next, the test administrator briefed the subject on the purpose of the study and showed him the test materials.

Testing began with the TM questions for one of the tests. Immediately after answering the last question, the subject began the hands-on part of the test and the test administrator started the stop watch. During the performance of each step, the test administrator checked each scoring criterion for accuracy. Errors were indicated on the test in two ways: (1) by deducting a point from the appropriate scoring criterion, and (2) by annotating the inappropriate action in the right-hand margin. Once the subject indicated that the repair was completed, his time was recorded and he was asked to remove all replaced parts and return them to the display board. These removal steps were not scored, but were necessary to set up the test site for the next subject.

The second test began immediately after the parts from the first test had been returned. Once the second test was completed, the subject performed the installation steps in reverse and returned all parts to the display board as before. During this activity, the test administrator tallied the points earned on each test.

---

[1] Spiker, V. A. **Maintenance performance systems (organizational). Test administrator's guide for MOS 63N maintenance proficiency test.** Santa Barbara, CA: Anacapa Sciences, Inc. (Technical Report 465-22), August 1982.

The subject was given his total proficiency score on each test, as well as each subtest score. Feedback on individual steps that posed particular difficulties was also given to the subjects. Total administration time for both tests ranged from two to three hours.

The collected data were coded, keypunched, and stored on an NASCO AS/6 computer at the University of California, Santa Barbara. The data were subsequently processed using the Statistical Analysis System.[1]

---

[1] Helwig, J. T., & Council, K. A. **SAS user's guide, 1979 edition.** Cary, North Carolina: SAS Institute, Inc., 1979.

RESULTS

The study provided answers to four specific research questions:

- **How closely related are JE and tested maintenance proficiency?** JE was strongly correlated with maintenance proficiency, accounting for one-half of the total variation in the test data.

- **What is the nature of the relationship between JE and maintenance proficiency?** Proficiency increases sharply with JE, peaks between 5 and 6 exposures, and declines slightly with exposures beyond 6 on the tasks tested.

- **How generalizable is the relationship?** Comparable results were obtained for the two different maintenance tasks, suggesting that the functional relationship is reliable and generalizable to tasks of this type. However, starter and generator installation are but two of the many corrective maintenance tasks performed by the 63N mechanic.

- **Does JE reflect the various dimensions of maintenance work?** Similar functional relationships were found between JE and measures of six different aspects of maintenance work. These results suggest that JE reflects different components of maintenance proficiency--quality, procedural, time, information use, and tool selection and use.

Mean test scores for every combination of scoring criterion, task, and JE category are summarized in Appendix D. The methods used to pool and analyze the data are described in Appendix E.

Results of the analysis of the overall proficiency data, and the data from the individual subtests, are described in the sections below.

EFFECT OF JOB EXPOSURE ON OVERALL MAINTENANCE PROFICIENCY

The relationship between JE and proficiency was quite strong, with JE accounting for approximately one-half the variance in the data in each test. Overall mean tested proficiency plotted as a function of JE for the starter and generator tests separately is shown in Figure 2. The JE effect easily reached statistical significance in both tests ($p < .01$).

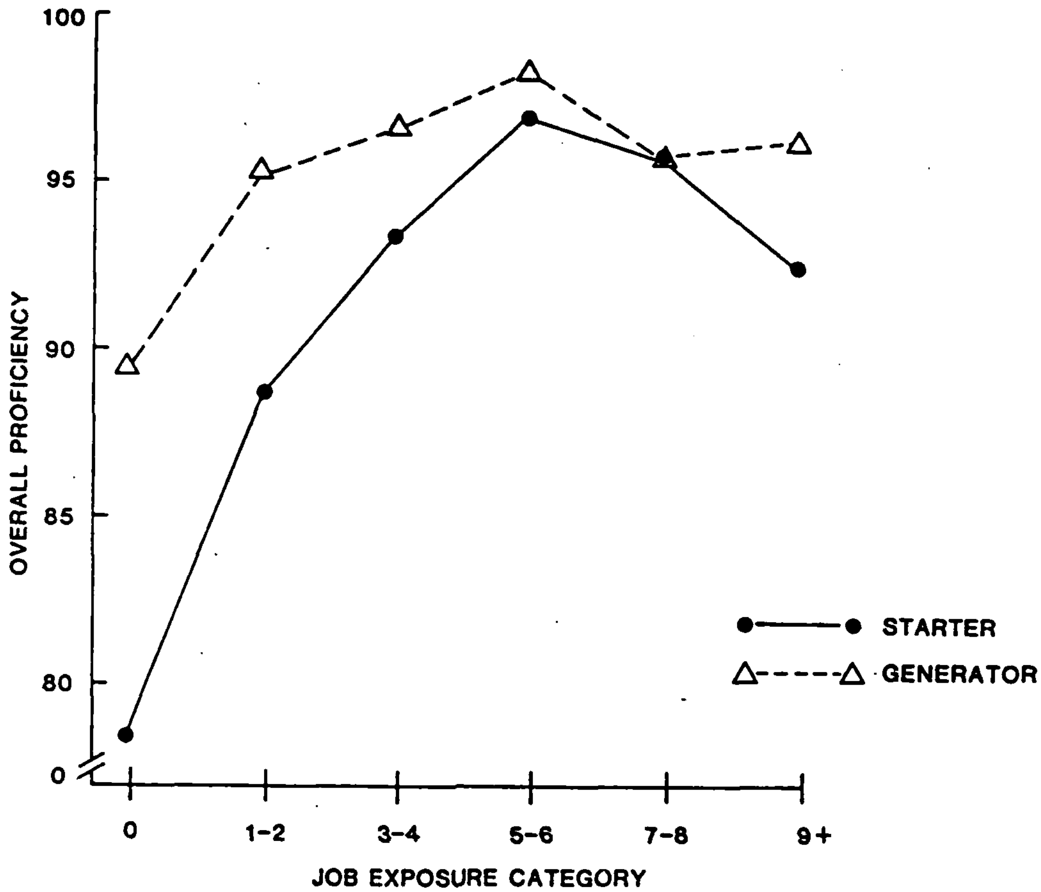


Figure 2. Effect of job exposure on overall repair proficiency.

The JE curves for both tests are characterized by proficiency rising markedly over the lower range of JE values, peaking at 5 to 6 exposures, and then declining slightly. Overall test performance was relatively good, with only the subjects who had not previously performed the task scoring below 80. Overall proficiency was consistently higher on the generator test, mainly because the starter required less time to install.

EFFECT OF JOB EXPOSURE ON REPAIR TIME

Mean time to complete the test decreased generally with JE, reached a minimum, and then increased slightly at the greatest JE categories for both starter and generator repair tasks. These results are shown in Figure 3. The decline in

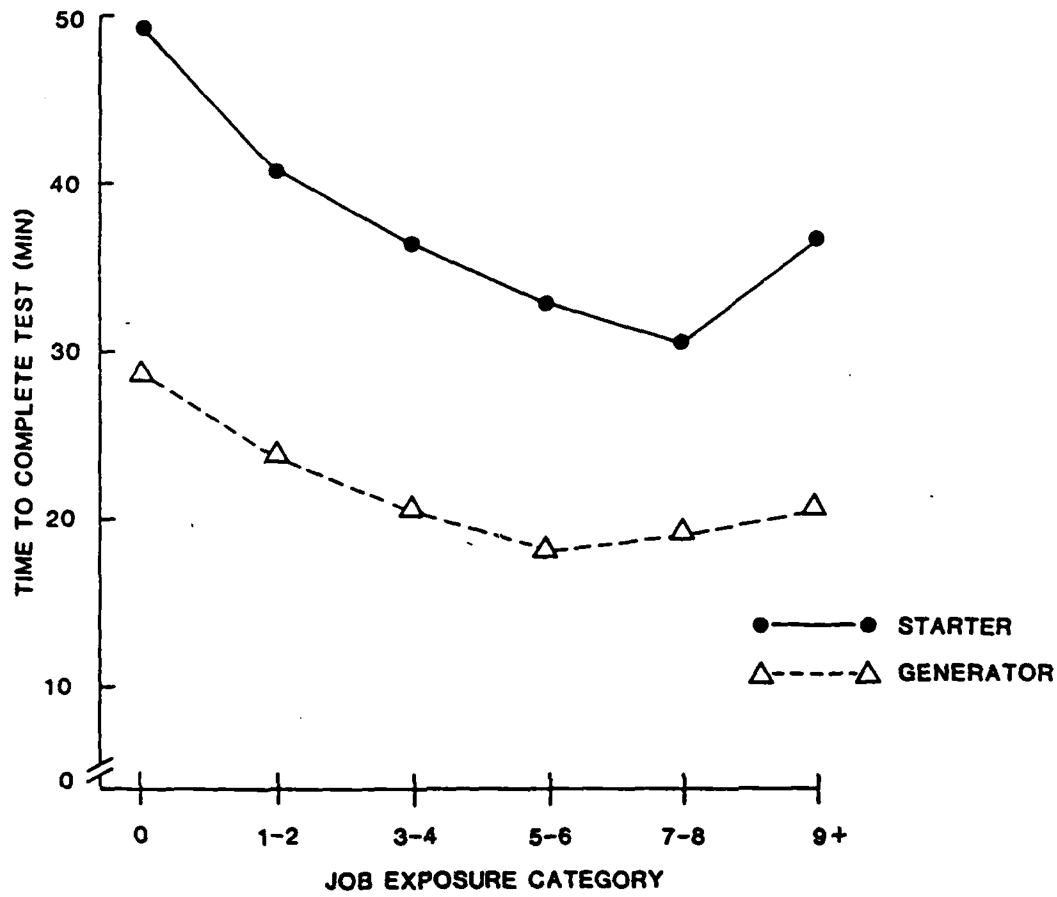


Figure 3. Effect of job exposure on time to complete test.

mean time across JEs implies more efficient performance and is thus consistent with the results for total proficiency. The JE effect on the time to install the starter was especially strong, accounting for almost half the total data variance. A weaker relationship was found in the generator data, with JE accounting for 34% of the test data variance.

Consistent with the proficiency data, the time curves for the two tests are roughly parallel, with the starter taking 15-20 fewer minutes to install than the generator. For both tests, the decrease in repair time over the lower JE values and the slight increase at the highest JE category were statistically significant. Fastest starter installation times were recorded by mechanics in JE Category 7-8, with a mean slightly under 31 minutes. Generator installation was fastest for mechanics in JE Category 5-6, with a mean time slightly over 18 minutes.

EFFECT OF JOB EXPOSURE ON REPAIR ACCURACY

Similar results were obtained from an aggregate score of repair accuracy as were obtained from the individual subtest scores of: TM knowledge, following the prescribed step sequence, tool selection/use, and quality check of key performance steps. To allow the scores from the two tests to be plotted on the same scale, accuracy was converted to a percentage by dividing the summed score by the maximum points possible, 75 for the starter test and 67 for the generator test, and multiplying by 100. Percent total accuracy is plotted as a function of JE in Figure 4.

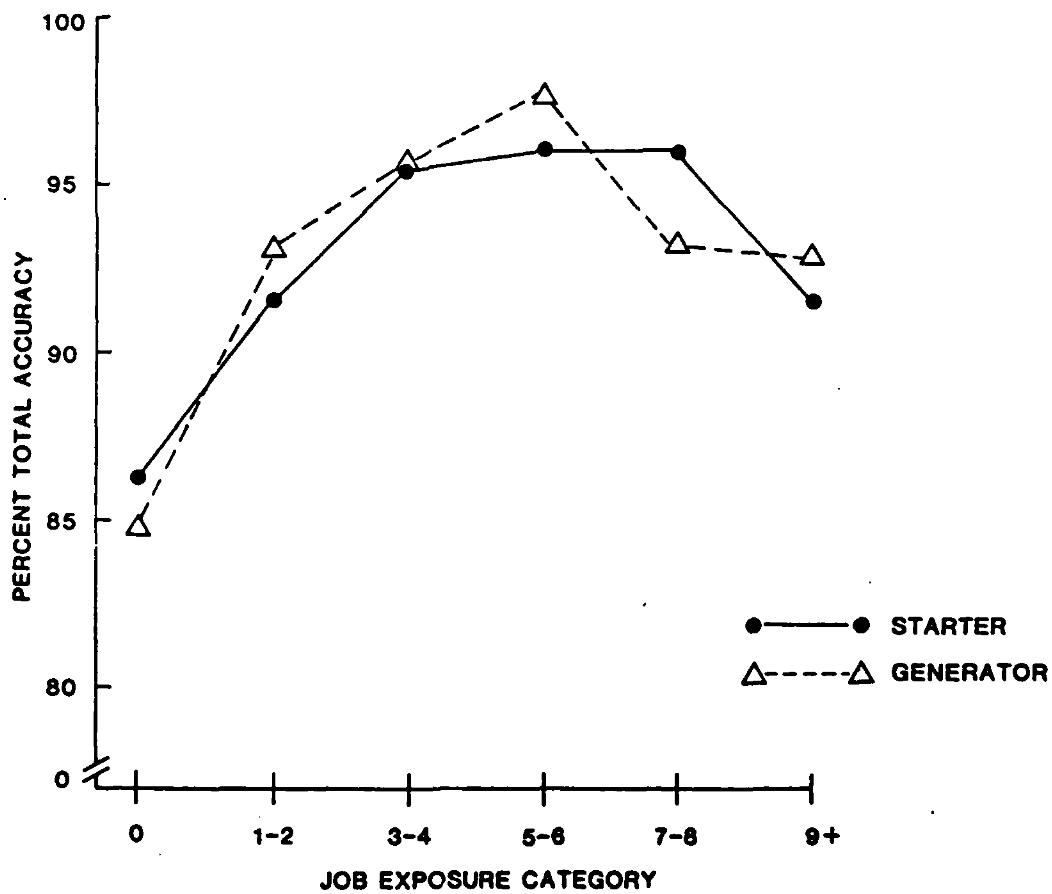


Figure 4. Effect of job exposure on total repair accuracy.

A strong functional relationship was found between JE and repair accuracy, similar to the relationship between JE and overall repair proficiency. In both tests, the JE curve has a significant linear rise, a peak at JE Category 5-6, followed by a significant decline in performance for the two highest JE categories. Note that repair accuracy was comparable on the two tests, indicating that the better overall proficiency observed in the starter test was due to speed rather than accuracy.

The relationship between JE and repair accuracy was examined further by separately analyzing the data for each individual accuracy measure. In general, these individual analyses support the conclusions based on the analysis of total repair accuracy.

Effect of Job Exposure on TM Knowledge

Average scores on the 10 TM questions were converted to percentage form and displayed in Figure 5. Consistent with the analysis of total accuracy, subjects' TM

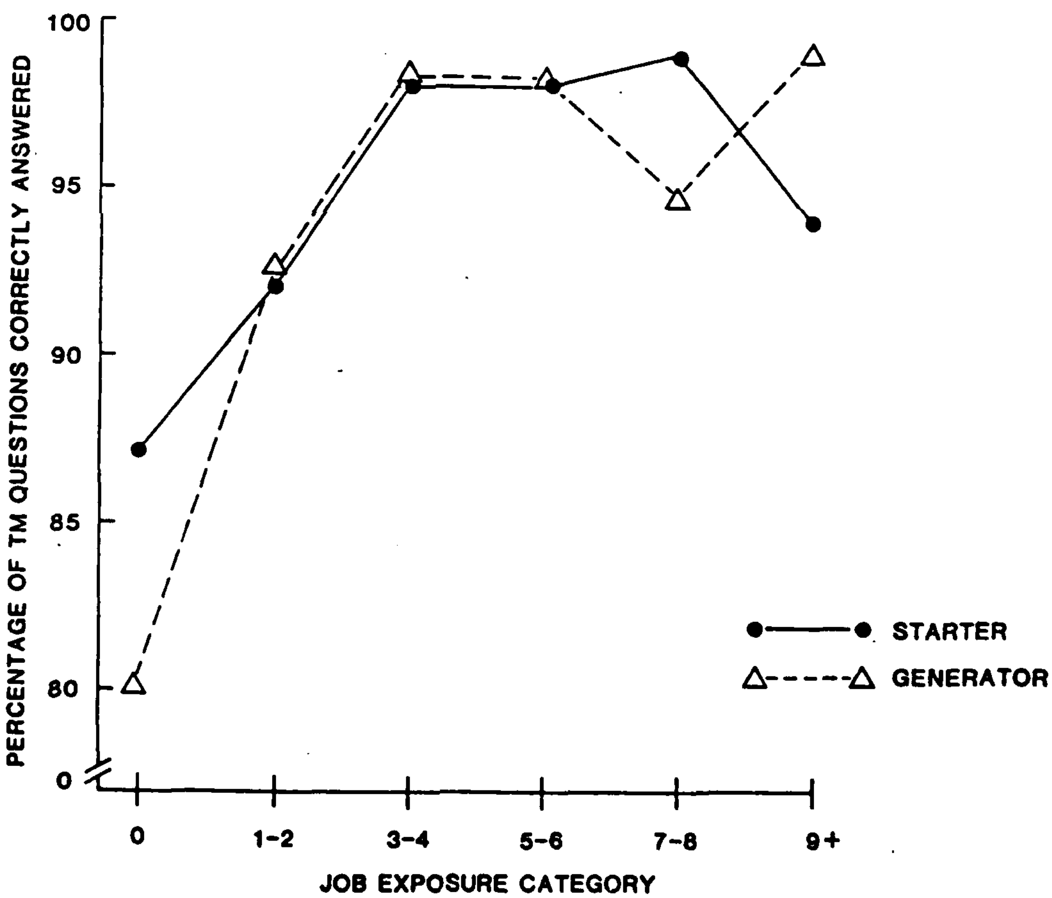


Figure 5. Effect of job exposure on knowledge of technical manual.

performance improved as a function of JE, reaching a peak at JE Category 7-8 on the starter test and 5-6 in the generator test. Performance declined in different JE categories for the two tests. Mean starter test performance dropped by 5% for mechanics in the highest JE category; generator TM performance decreased for subjects in the 7-8 category but then rose 4% for the most experienced mechanics.

Effect of Job Exposure on Following Correct Step Sequence

The percentage of performance steps correctly followed is plotted as a function of JE in Figure 6. Like the previous analyses of accuracy, the sequence criterion shows a significant increase, a peak, and then a significant decrease over JE. Sequence performance was comparable between the two tests, with maximum performance observed in JE Category 7-8 for the starter test and 5-6 for the generator test. Performance within a JE category was more variable than in other measures, as reflected in the finding that JE accounted for only 20% of the data variance for each test.

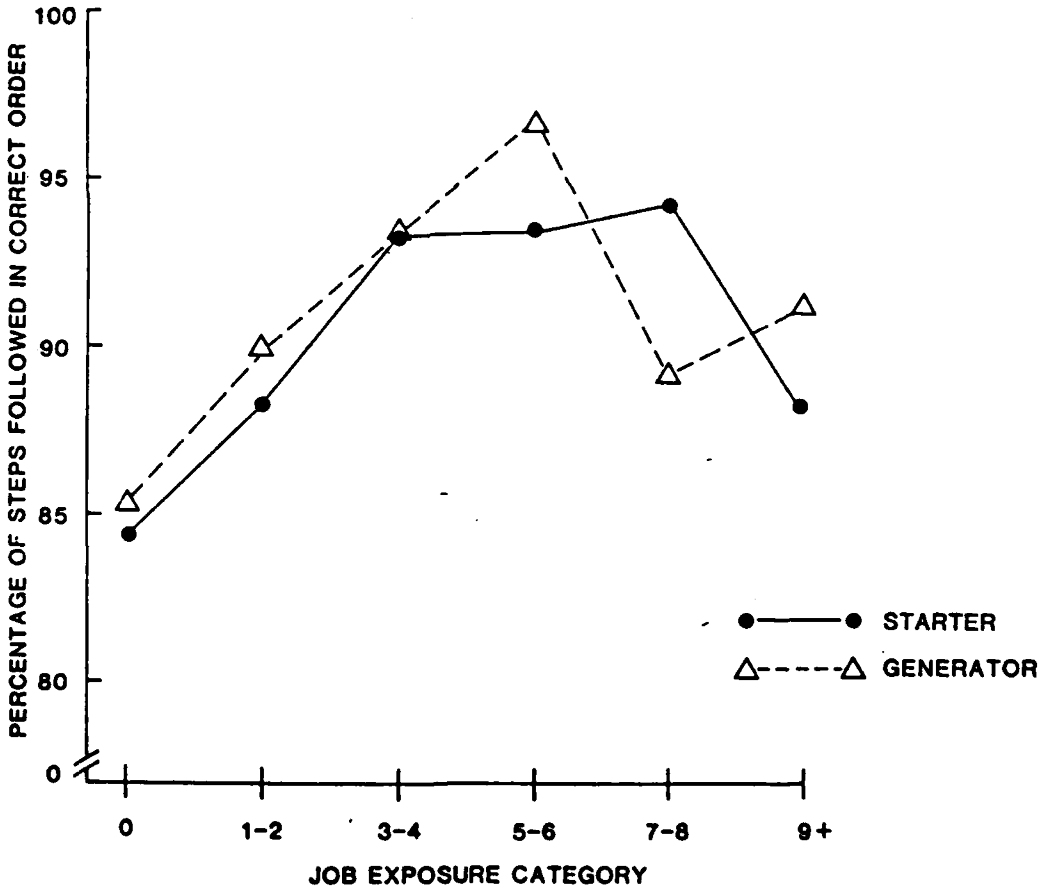


Figure 6. Effect of job exposure on following correct step sequence.

Effect of Job Exposure on Tool Use/Selection

The combined tool selection/use criterion was converted to a percentage and plotted over JE categories as shown in Figure 7. The statistically significant proficiency growth with JE peaked at JE category 7-8 for both tests. The average tool selection/use score was consistently higher in the starter test, though not by much. The biggest improvement in tool performance was noted between the 0 and 1-2 categories, increasing by 5% in the starter test and 11% for the generator test.

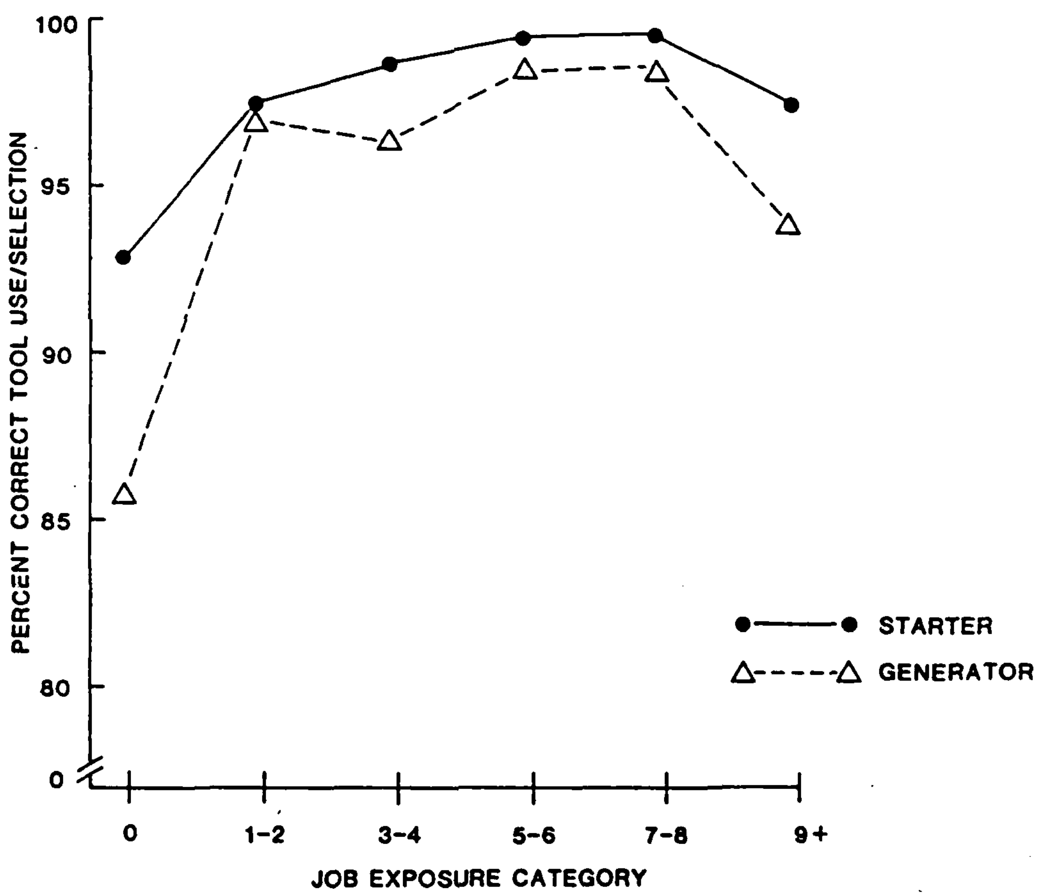


Figure 7. Effect of job exposure on tool selection/use.

The size of these increases supports the notion that proper tool selection and use is a primary skill component that mechanics should acquire early in their career.

Effect of Job Exposure on Checking the Quality of Key Steps

Number of key steps correctly checked for quality was converted to a percent and plotted over JE as shown in Figure 8. The two JE curves diverge markedly, requiring that the results from the two tests be discussed separately.

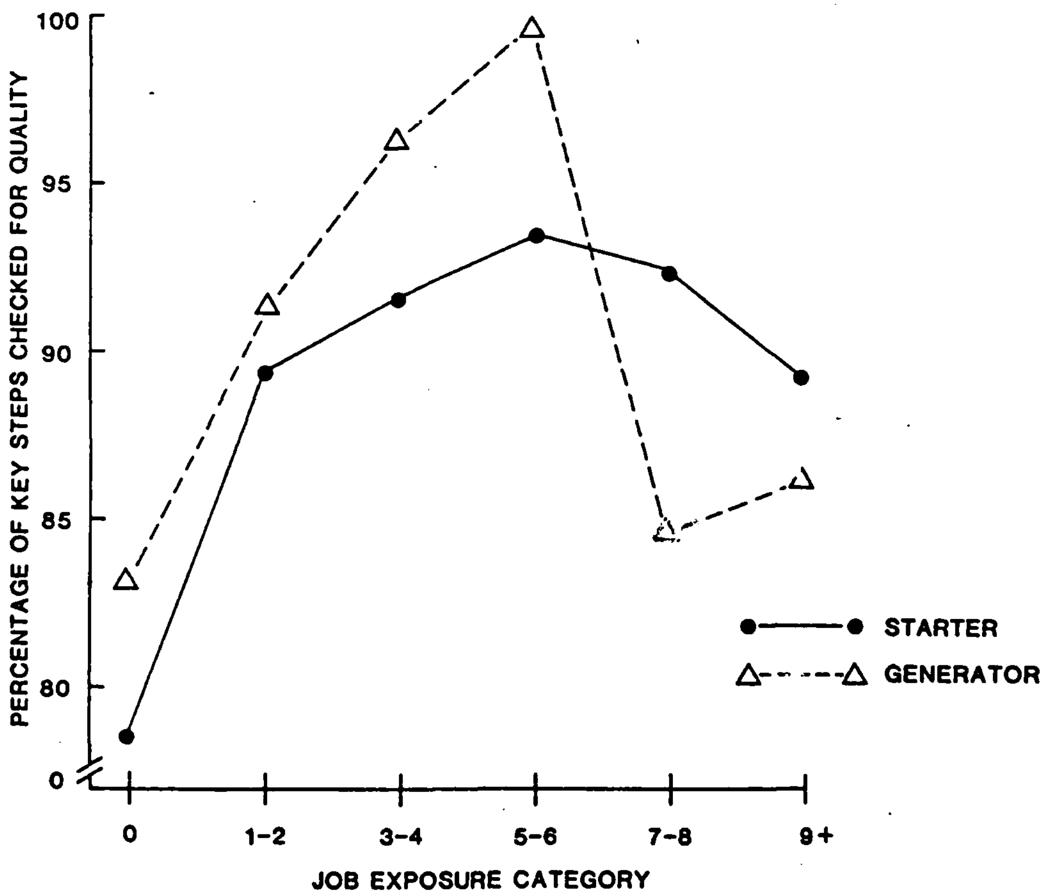


Figure 8. Effect of job exposure on checking quality of key steps.

Considering the starter test first, performance showed a systematic and significant increase over the lower JE categories, a peak at 5-6, and a significant decline in the two highest categories. Performance within categories was variable, with JE explaining only slightly more than 20% of the total variance.

The percentage of key generator installation steps checked for quality varied substantially between the low and high JE categories. In particular, the 15% drop between the 5-6 and 7-8 JE categories placed the performance of the most experienced mechanics at levels comparable to those of beginners. This equivalence made the overall effect of JE on quality check nonsignificant, invalidating further statistical testing of individual mean differences.

The generator data should be interpreted cautiously, however, since quality scores were based on only three steps. While it is safe to conclude that performance by the most experienced mechanics is lower than that of moderately experienced mechanics, the observed decline to a level equal to the beginning mechanic may be exaggerated because of the small sample of steps contained in the criterion.

CONCLUSIONS AND IMPLICATIONS

A strong positive relationship was found between JE and maintenance proficiency, in both repair accuracy and repair speed. These results suggest that JE is a valid, easy-to-collect indicator of the skill development of maintenance personnel. As a consequence, JE is likely to be a useful index for monitoring individual skill growth and identifying skill development needs.

IMPLICATIONS FOR MPS(O)

The strong, reliable, generalizable relationship between JE and tested maintenance proficiency supports the use of JE for monitoring mechanic skill growth and targeting OJT in the MPS(O). The JE is likely to provide meaningful profiles of the task proficiency of individual mechanics, and useful indices of mechanic skill growth within units. Mechanics with little or no JE on a given task are likely to be most deficient in repair skill, most in need of OJT, and most likely to benefit from supervised practice. As JEs accrue, the maintenance proficiency of the unit should also grow.

IMPLICATIONS FOR OJT

It is worth noting that many subjects praised the test conditions as providing a good training vehicle for the two repair tasks. These compliments were amplified by the mechanics' supervisors. The opportunity to perform repairs on real equipment, under quiet conditions, and in the presence of immediate feedback from an expert prompted phrases like "its a great way to learn" and "sure wish I'd had this in AIT."

The test conditions employed in this study could be readily adapted for use in OJT. For example, mechanics having few JEs on a given task might be singled out for performance testing under "OJT conditions." These conditions would consist of the requisite repair equipment (e.g., a detached tank engine if the task required it), TMs, tools, and repair parts. All materials would be housed in a secure, enclosed area of the motor pool. OJT candidates would be formally scheduled for the test in advance, and would perform the repair under the watchful eye of a senior maintenance technician. Immediate and detailed feedback on each performance step would be given. Besides providing task-related feedback, the OJT session would also cover: how to read a TM, the general principles governing proper tool use, and the importance of working to specifications. To the extent that company training managers fostered the motivation for, and garnered the resources to sustain, such a program, the overall level of repair proficiency would likely increase rapidly.

IMPLICATIONS FOR FURTHER RESEARCH

A single study cannot possibly resolve every major issue in its area. In the present context, additional research pertinent to the relationship between JE and repair skill is desirable on two fronts:

The JE-Proficiency Relationship Should be Examined for Other Repair Tasks and Other MOSs

Can the conclusions drawn from these data be applied to other 63N repair tasks and to tasks performed by other mechanic MOSs? Starter and generator installation are representative of many repairs performed at the organizational level, but other qualitatively different repair tasks are performed as well. For instance, would the same function be obtained on an easier task, such as adjust/replace minor components; on a more complex task, like troubleshooting/diagnosis? Similar questions regarding generalizability should also be addressed for other mechanic MOSs, such as turret mechanics (45N), radio repairmen (31V), or wheeled vehicle repairmen (63B/S). Studies using a design similar to this one could be conducted on other tasks and MOSs to shed light on the issue of generalizability.

The JE-Proficiency Relationship for Mechanics Having 10 or More JEs Should be Examined Further

How reliable and widespread is the less-than-optimal repair proficiency of the most experienced subjects? Only 28 such mechanics were included in the present study, so a full-scale repeat of the study on a larger group of experienced mechanics is needed. The study should be conducted at another site to determine if the effect described in this report is unique to Fort Carson. If it is not, then the major role that senior mechanics should play in future OJT efforts may have to be redefined. Finally, future research should also examine the contribution of specific factors to this drop in repair proficiency, such as lack of motivation, out-dated technical knowledge, false confidence in the mechanic's own ability, and unwillingness to retrieve and consult appropriate technical manuals.

APPENDIX A

TEST (M60 CM3-63N) - INSTALL A STARTER

ORGANIZATIONAL MAINTENANCE TEST ADMINISTRATOR'S GUIDE

MOS 63N MAINTENANCE PROFICIENCY TEST

OBJECTIVE

- TASK
  - **Install a starter on a 2C M60A1 RISE Passive tank engine** (includes installation of starter low voltage relay solenoid).
- CONDITIONS
  - Powerplant removed from M60A1 RISE Passive tank
  - Starter (and solenoid) removed from powerpack -Cables already tagged

  To be available on-site:

    — TM 9-2350-257-20-1 Vols. 1 through 4

    — One assistant

    — 63N mechanic's tool kit

    — A copy of the test

    — All tools and supplies listed on page 10-23 and page 10-30, TM 9-2350-257-20-1-3

    — Replacement starter

- INFORMATION FOR ADMINISTRATOR ONLY
  - This task will require an assistant mechanic.
- STANDARD
  - Task will be completed in 60 minutes.
  - TM references for sequence, tolerances will be followed, if available.
  - Safety precautions will be observed.

ADMINISTRATOR'S NOTES

Background

- **You must know this task before giving the test.** The task is explained in detail in pages 10-27 through 10-29, TM 9-2350-257-20-1-3. Steps 1 to 14 on pages 10-27 through 10-29 and steps 1 and 2 on page 10-31 constitute the material in the test.
- You will need a stopwatch or wristwatch.
- Interfere with the test **only** if a hazardous situation is developing.

Immediately Before the Test

- Check that the man who reports for the test has been assigned by Anacapa.
- Emphasize the purpose of the test is to help find out what additional skill training is needed that will further his career and improve maintenance.
- Read him the task, condition and standards.
- Ask the examinee for the number of times he has performed this task since AIT. Record on page d.
- Ask the examinee how long it has been since he last performed this task on the line, or since AIT if he has no previous line experiences for this task. Record on page d.
- Tell him you'll review his results with him immediately after the test.
- Explain that the test is in two parts:
  - Part 1 - A short test (10 questions) of general knowledge related to the task
  - Part 2 - A "hands-on" demonstration of the task
- Explain that he may use any of the reference materials provided in any way he feels will help him complete the test.
- Explain that the 10 questions in Part 1 are **not timed.**

During the Test

- Now ask him the questions in Part 1 and record his score. (The test question sheets are also your score sheets.)
- Explain that he will now do the task in Part 2.
- Tell him he has **60** minutes to do the task but that you won't start timing till he says he is ready.
- Start timing on his signal and record his scores.
- If an unavoidable distraction arises during the test, temporarily suspend timing until the distraction is taken care of. Then, resume timing.
- Constantly safeguard the mechanic against hazardous situations.
- Stop timing when he says the job is finished.

After the Test

- Compute the score.
- Explain the scoring system to the mechanic and review the results with him.
- Correct any procedural or quality errors, and safety violations at this point.
- Have the mechanic sign the Test Grade Computation Sheet agreeing he has received feedback.

TEST SCORING NOTES*

Part 1 (Not timed) is scored by awarding 1 point for each correct answer. ("Correct answers" may be given orally, or by the mechanic pointing to the manual or part, related to the test question.)

Part 2 (Timed—60 minutes allowed) is scored by awarding 1 point each for:

- Maintaining the performance step sequence**
- Selecting the correct tool(s)
- Using tool(s) properly
- Working to specifications/tolerances

To Compute the Test Grade for Part 2

Add across each row by page to get score for each performance component.

Add each column to find mechanic's total scores on tool selection and use, working to specs, etc.

Add totals across bottom row, page 4, to get **overall test score.**

If Part 2 is completed with an overall score of 52 within the time blocks shown, add the incremental points as shown in the table below. If Part 2 is completed but outside the time limits, **no** incremental points are awarded.

Incremental Points for Completion to Time Standard

If mechanic has a score of **at least** 52 on Part 2

AND

- Has completed the test in under 40 minutes—**add 25 points** to his score
- Has completed the test in 41-48 minutes—**add 18 points** to his score
- Has completed the test in 49-55 minutes—**add 11 points** to his score
- Has completed the test in 56-60 minutes—**add 4 points** to his score
- Has completed the test in over 60 minutes—**add 0 points** to his score

*A computation sheet is provided on page d.
**The TM will be the reference authority for sequence, tools, and specifications, if appropriate. If not, use local standards and procedures.

TEST GRADE COMPUTATION SHEET

	Possible Points		Actual Points	
Part 1 - 10 points	10		____	
Part 2				
Done in correct sequence -	31	65	____	____
Selection of correct tool -	11		____	
Correct use of tool -	11		____	
Working to correct specs -	12		____	
Time for Performance				
If score for Part 2 = **58** and over				
and Performance is **under 40** minutes, add (full credit)	25	25	Select only one	____
Performance **in 41-48** minutes add (partial credit)	18			
Performance **in 49-55** minutes add (partial credit)	11			
Performance **in 56-60** minutes add (partial credit)	4			
Performance **60** minutes add (no credit)	0			
Total Possible = Points	100		**Actual Points = Scored**	____

TESTEE DATA

Date ____________________

1. **Name** ______________________________ **SSN** ______________
2. ______________________________ **Primary MOS**
3. ______________________________ **AIT**
4. ______________________________ **Number of Prior Task Experiences**
5. ______________________________ **Number of Days Since Last Performance**
6. ______________________________ **Time Taken for Test** Finished ________ Started ________

- **Received debriefing X** ______________________________

PART 1: GENERAL BACKGROUND KNOWLEDGE RELATED TO TM USE IN TEST

(one point for each correct answer)

Points

*1. What current TM series has organizational maintenance information for the M60A1 RISE Passive 2C engine?

ANS: TM 9-2350-257-20 series ___

2. What is the date of the latest revision?

ANS: January 1981 ___

3. Which volume of the TM tells how to remove and install the starter?

ANS: TM 9-2350-257-20-1-3 (Volume 3) ___

4. Is a special tool required to remove and install the starter?

ANS: Yes (see special tools, page 10-23, TM 9-2350-257-20-1-3 or TM 9-2350-257-20-1-1, page 3-1) ___

5. Show me (in the TM) where it notes how much gap is allowed between the starter case and support cradle assembly.

ANS: Page 10-28, Step 9, TM 9-2350-257-20-1-3 (NOTE, no gap allowed) ___

6. Show me (in the TM) how much torque pressure is needed for the nuts holding the cables to the large terminal of the starter motor.

ANS: Page 10-29, Step 13, TM (as above) (168-192 lb-in or 19-22 N m) ___

7. What are the slip joint pliers used for on this job?

ANS: To fit lockwire on screws holding starter cradle and bracket to oil pan. ___

8. What goes between the starter and the starter drive adaptor?

ANS: A gasket. ___

9. What special tool is used to tighten the self-locking nuts on the starter drive adaptor bolts?

ANS: Special wrench ___

10. When do you install the starter low voltage relay solenoid?

ANS: After the starter is installed and connected ___

(Total Possible Points = 10)

Total Actual Points =

***Ask "Have you taken any previous NAST(I)'s for this equipment?" If YES - Award 2 points and go to 3. If NO - Start at 1.**

PART 2: HANDS-ON PERFORMANCE TEST

Derived from TM#*	Performance Component Step	Done in Correct Sequence	Selection of Correct Tool	Correct Use of Tool	Checking Quality Against Standard	Total Possible	Comments
1.	Install new gasket on starter drive adapter.	1	-	-	1	2	
2a.	Ease starter into starter drive adapter.	1	-	-	-	1	
b.	(Support starter) install new self-locking nut on upper bolt of drive adapter.	1	-	-	-	1	
c.	Hold the bolt with a 15/16" wrench and tighten nut with special wrench.	1	½ ½	½ ½	-	3	
3a.	Install a new self-locking nut on the bottom (outboard) bolt of drive adapter.	1	-	-	-	1	
b.	Hold the bottom (outboard bolt with a 15/16" wrench and tighten nut with special wrench.	1	½ ½	½ ½	-	3	
4a.	With fingers, start a new self-locking nut on the bottom (inboard) bolt of drive adapter.	1	-	-	-	1	
4b.	Tighten nut with special wrench.	1	1	1	-	3	
5.	Slide cradle assembly into position on starter.	1	-	-	1	2	
6.	With fingers, install three screws (bolts) and flat washers to secure starter cradle assembly bracket to engine oil pan.	1	-	-	-	1	
Possible Subtotals		10	3	3	2	18	
	Actual Subtotals	___	___	___	___	___	

*Steps 1-14, pages 10-27 through 10-29, TM 9-2350-257-20-1-3

Derived from TM#	Performance Component Step	Done in Correct Sequence	Selection of Correct Tool	Correct Use of Tool	Checking Quality Against Standard	Total Possible	Comments
7a.	With fingers, install double-braided ground straps with screw (bolt) and flat washer.	1	-	-	-	1	
b.	Ensuring flat washer seats flat against bracket face, install screw (bolt) to starter cradle assembly bracket and engine oil pan.	1	-	-	-	1	
8a.	Tighten self-locking nuts on U-bolts evenly with 1/2" wrench.	1	1	1	1	4	
b.	Ensure U-bolts are seated properly.	1	-	-	1	2	
9a.	Tighten the four screws (bolts) and flat washers securing the starter cradle assembly bracket to engine oil pan with 9/16" socket and extension	1	1	1	-	3	
b.	Ensure there is no gap between starter case and cradle assembly.	1	-	-	1	2	
c.	Adjust position of cradle assembly, if needed. (1)	1	-	-	1	2	
10a.	Install low voltage relay solenoid bracket to engine oil pan with four screws and lock washer	1	-	-	1	2	
b.	Tighten the screws with ½" socket and extension.	1	1	1	-	3	
Possible Subtotals		9	3	3	5	20	
	Actual Subtotals	___	___	___	___	___	

(1) If cradle assembly does not need adjusting award 2 points.

Derived from TM#	Performance Component Step	Done in Correct Sequence	Selection of Correct Tool	Correct Use of Tool	Checking Quality Against Standard	Total Possible	Comments
11.	With screwdriver, connect small cable to bottom front of starter switch solenoid relay with screw and external tooth lockwasher.	1	1	1	1	4	
12a.	Connect heavy cables and small cable to bottom terminal of starter switch relay solenoid with nut and lockwashers.	1	-	-	-	1	
b.	Tighten nut to 168-192 lb-in (19-22 N m) with 3/4" socket and torque wrench.*	1	1	1	1	4	
13a.	Connect double-braided ground straps, heavy cables, and small cable to large terminal with nut and lockwashers.	1	-	-	-	1	
b.	Tighten nut to 168-192 lb-in (19-22 N m) with 3/4" socket and torque wrench.*	1	1	1	1	4	
	(Now go to page 10-31 for performance step breakdown)						
1a.	Place insulators between low voltage relay solenoid and engine mounting bracket.	1	-	-	1	2	
b.	Place LV relay solenoid over mounting bracket on insulators with electrical plug facing front.	1	-	-	1	2	
c.	Secure solenoid to plate with screws, and new self-locking nuts.	1	-	-	-	1	
d.	Tighten with 7/16" socket.	1	1	1	-	3	
Possible Subtotals		9	4	4	5	22	
	Actual Subtotals	___	___	___	___	___	

*Test Administrator: Check reading.

Derived from TM#	Performance Component Step	Done in Correct Sequence	Selection of Correct Tool	Correct Use of Tool	Checking Quality Against Standard	Total Possible	Comments
2a.	Screw electrical connectors on relay solenoid.	1	-	-	-	1	
b.	Tighten connectors with spanner wrench.	1	1	1	-	3	
	GO TO NEXT STEP BUT DO NOT HAVE TRAINEE PERFORM—ASK:						
	What is the next step? (ANS: Ground-hop test)	1	-	-	-	1	
	NOW STOP TEST!						
Possible Subtotals		3	1	1	-	5	
	Actual Subtotals	___	___	___	___	___	
Possible Column Totals		31	11	11	12	65	
	Actual Totals	___	___	___	___	___	

APPENDIX B

TEST (M60 CM4-63N) - INSTALL A GENERATOR

ORGANIZATIONAL MAINTENANCE
TEST ADMINISTRATOR'S GUIDE

MOS 63N MAINTENANCE PROFICIENCY TEST

OBJECTIVE

- **TASK**

  - **Install a generator on a 2C M60A1 RISE Passive tank engine**

- **CONDITIONS**

  - Powerplant removed from M60A1 RISE Passive tank

  - Generator removed from powerpack

  To be available on-site:
  - Replacement generator ready for installation, with fittings and hose assemblies installed
  - 63N mechanic's tool kit
  - Special tools
  - TM 9-2350-257-20-1-1 through -1-4
  - One assistant
  - A copy of the test

- **INFORMATION FOR ADMINISTRATOR ONLY**

  - This task will require an assistant mechanic.

- **STANDARD**

  - Task will be completed in 60 minutes.

  - TM references for sequence, tolerances will be followed, if available.

  - Safety precautions will be observed.

ADMINISTRATOR'S NOTES

Background

- **You must know this task before giving the test.** The task is explained in detail in pages 10-9 through 10-11, TM 9-2350-257-20-1-3. Steps 12-35 constitute the material in the test.
- You will need a stopwatch or wristwatch.
- Interfere with the test **only** if a hazardous situation is developing.

Immediately Before the Test

- Check that the man who reports for the test has been assigned by Anacapa.
- Emphasize the purpose of the test is to help us find out what additional skill training is needed that will further his career and improve maintenance.
- Read him the task, condition and standards.
- Ask the examinee for the number of times he has performed this task since AIT. Record on page d.
- Ask the examinee how long it has been since he last performed this task on the line, or since AIT if he has no previous line experiences for this task. Record on page d.
- Tell him you'll review his results with him immediately after the test.
- Explain that the test is in two parts:
  - Part 1 - A short test (10 questions) of general knowledge related to the task
  - Part 2 - A "hands-on" demonstration of the task
- Explain that he may use any of the reference materials provided in any way he feels will help him complete the test.
- Explain that the 10 questions in Part 1 are **not timed.**

During the Test

- Now ask him the questions in Part 1 and record his score. (The test question sheets are also your score sheets.)
- Explain that he will now do the task in Part 2.
- Tell him he has **60** minutes to do the task but that you won't start timing till he says he is ready.
- Start timing on his signal and record his scores.
- If an unavoidable distraction arises during the test, temporarily suspend timing until the distraction is taken care of. Then, resume timing.
- Constantly safeguard the mechanic against hazardous situations.
- Stop timing when he says the job is finished.

After the Test

- Compute the score.
- Explain the scoring system to the mechanic and review the results with him.
- Correct any procedural or quality errors, and safety violations at this point.
- Have the mechanic sign the Test Grade Computation Sheet agreeing he has received feedback.

TEST SCORING NOTES

Part 1 (Not timed) is scored by awarding 1 point for each correct answer. ("Correct answers" may be given orally, or by the mechanic pointing to the manual or part, related to the test question.)

Part 2 (Timed—60 minutes allowed) is scored by awarding 1 point each for:

- Maintaining the performance step sequence*
- Selecting the correct tool(s)
- Using tool(s) properly
- Working to specifications/tolerances

To Compute the Test Grade for Part 2

Add across each row by page to get score for each performance component.

Add each column to find mechanic's total scores on tool selection and use, working to specs, etc.

Add totals across bottom row, page 4, to get **overall test score.**

If Part 2 is completed with an overall score of **46** within the time blocks shown, add the incremental points as shown in the table below. If Part 2 is completed but outside the time limits, **no** incremental points are awarded.

Incremental Points for Completion to Time Standard

If mechanic has a score of **at least 46** on Part 2

AND

- Has completed the test in under 40 minutes—**add 33 points** to his score
- Has completed the test in 41-48 minutes—**add 24 points** to his score
- Has completed the test in 49-55 minutes—**add 15 points** to his score
- Has completed the test in 56-60 minutes—**add 6 points** to his score
- Has completed the test in over 60 minutes—**add 0 points** to his score

*A computation sheet is provided on page d.
**The TM will be the reference authority for sequence, tools, and specifications, if appropriate. If not, use local standards and procedures.

TEST GRADE COMPUTATION SHEET

	Possible Points		Actual Points	
Part 1 - 10 points	10			____
Part 2				
Done in correct sequence -	30	57	____	____
Selection of correct tool -	12		____	
Correct use of tool -	12		____	
Working to correct specs -	3		____	
Time for Performance				
If score for Part 2 = 46 and over				
and Performance is under 40 minutes, add (full credit)	33	33	Select only one	____
Performance in 41–48 minutes add (partial credit)	24			
Performance in 49–55 minutes add (partial credit)	15			
Performance in 56–60 minutes add (partial credit)	6			
Performance over 60 minutes add (no credit)	0			
Total Possible Points =	100		Actual Points Scored =	____

TESTEE DATA

Date ____________________

1. Name ________________________________ SSN ____________________
2. ____________________________ Primary MOS
3. ____________________________ AIT
4. ____________________________ Number of Prior Task Experiences
5. ____________________________ Number of Days Since Last Performance
6. ____________________________ Time Taken for Test Finished ________ Started ________

- Received debriefing X ____

PART 1: GENERAL BACKGROUND KNOWLEDGE RELATED TO TM USE IN TEST
(one point for each correct answer)

Points

*1. Show me the TM that has organizational maintenance information for the M60A1 RISE Passive 2C engine.

ANS: TM 9-2350-257-20 series ____

2. What is the date of the latest revision?

ANS: January 1981 ____

3. Which volume of the TM contains the troubleshooting procedures for the 2C engine?

ANS: TM 9-2350-257-20-1-1 (Volume 1) ____

4. How are the generators of 2A and 2D engines cooled?

ANS: Air ____

5. How is the generator of a 2C engine cooled?

ANS: Oil ____

6. Where should the oil inlet elbow of a 2C generator be positioned when you are installing it on the engine?

ANS: Down, at the bottom, or 6 o'clock position ____

7. Show me where it lists the torque pressure for the locknut of the V-band clamp that holds the generator tight to the drive adapter?

ANS: 55-65 lb in (or 6-7 N m) from TM 9-2350-257-20-1-3 (Volume 3) ____

8. Show me where it lists the correct idle speed for a "ground hop" powerplant test run?

ANS: 700-750 RPM from TM 9-2350-257-20-1-2 (Volume 2) ____

9. Will the tachometer operate during a "ground hop" powerplant test run?

ANS: No (Not connected) ____

10. What gauge should show that the generator is charging?

ANS: Battery generator ____

(Total Possible Points = 10)

Total Actual Points = ____

***Ask "Have you taken any previous NAST(I)'s for this equipment?" If YES - Award 2 points and go to 3. If NO - Start at 1.**

PART 2: HANDS-ON PERFORMANCE TEST

Derived from TM#*	Performance Component Step	Done in Correct Sequence	Selection of Correct Tool	Correct Use of Tool	Checking Quality Against Standard	Total Possible	Comments
12a.	(Using hydraulic jack), position generator and cradle assembly on generator bracket.	1	-	-	-	1	
b.	Slide forward until splined shaft engages.	1	-	-	-	1	
13.	Ensure oil inlet elbow is at 6 o'clock position and generator is tight against adapter.	1	-	-	-	1	
14.	Position V-band clamp around generator/adapter mating flange.	1	-	-	-	1	
15a.	Tighten locknut on V-clamp with 7/16" wrench.	1	1	1	-	3	
b.	Tighten locknut to 55-65 lb in (6-7 N m) *with 7/16" socket and* torque wrench.	1	1	1	1	4	
16.	Align screw mounting holes in cradle, with generator bracket (plastic hammer may be used).	1	-	-	-	1	
17.	Start two screws (bolts) with flat washers in holes.	1	-	-	-	1	
18.	Tighten screws using 9/16" socket.	1	1	1	-	3	
19.	Tighten T-bolt nut of cradle strap with 7/16" wrench.	1	1	1	-	3	
20a.	Connect oil inlet hose to elbow.	1	-	-	-	1	
b.	Tighten hose connection using 7/8" and 3/4" wrenches.	1	1	1	-	3	
Possible Subtotals		12	5	5	1	23	
	Actual Subtotals	____	____	____	____	____	

*Steps 12-35, pages 10-9/10-11, TM 9-2350-257-20-1-3

Derived from TM#	Performance Component Step	Done in Correct Sequence	Selection of Correct Tool	Correct Use of Tool	Checking Quality Against Standard	Total Possible	Comments
21a.	Connect vent hose to adapter.	1	-	-	-	1	
b.	Tighten connection using 9/16" and 1/2" wrenches.	1	1	1	-	3	
22a.	Connect oil return hose to adapter.	1	-	-	-	1	
b.	Tighten connection using 7/8" wrench.	1	1	1	-	3	
23a.	Connect oil return hose to adapter.	1	-	-	-	1	
b.	Tighten connection using 1/2" and 9/16" wrenches.	1	1	1	-	3	
24a.	Connect two electrical connectors.	1	-	-	-	1	
b.	Tighten connector 1 using 1" wrench.	1	1	1	-	3	
c.	Tighten connector 2 using 1-1/8" wrench.	1	1	1	-	3	
25a.	Remove nut from negative terminal.	1	-	-	-	1	
b.	Clean terminal if needed. (1)	1	-	-	1	2	
26.	Install bus bar (and attached ground straps) on negative terminal.	1	-	-	-	1	
27.	Install and tighten securing nut with 9/16" wrench.	1	1	1	-	3	
28a.	Remove nut from positive terminal.	1	-	-	-	1	
b.	Clean terminal if needed. (1)	1	-	-	1	2	
Possible Subtotals		15	6	6	2	29	
	Actual Subtotals	___	___	___	___	___	

(1) If terminal does not need cleaning, award 2 points.

Derived from TM#	Performance Component Step	Done in Correct Sequence	Selection of Correct Tool	Correct Use of Tool	Checking Quality Against Standard	Total Possible	Comments
29.	Install bus bar (with attached cable) on positive terminal.	1	-	-	-	1	
30.	Install nut securing bus bar and tighten with 9/16" wrench.	1	1	1	-	3	
31.	What is the next step? (ANS: Ground Hop Test)	1	-	-	-	1	
	Possible Subtotals	3	1	1	0	5	
	Actual Subtotals	____	____	____	____	____	
	Possible Column Totals	30	12	12	3	57	
	Actual Totals	____	____	____	____	____	

APPENDIX C
BRIEFING SCRIPTS

C-1: BRIEFING SCRIPT - TEST INTRODUCTION

Are you ____________ of ____ Company (or Bn, if necessary)? I am ____________. I represent Anacapa Sciences, Inc. We are doing research for the Army to help improve organizational maintenance proficiency. The company has been working at Fort Carson over the past several years. We are testing the repair skills of a number of mechanics like yourself to find better ways to organize training. I am required by law to provide this information about the test. (At this point cover the information on the "Research Participation Information Sheet" shown as Appendix C.)

You will be tested on two tank repair tasks, ***installing a starter*** *and* ***installing a generator****. Each test has two parts. The first part is worth 10 points and tests how well you can use the TM related to the repair task. In the second part of the test, worth 90 points, you will actually do the repair. Two-thirds of your score will be based on accuracy, doing the steps in the right order and using the right tools. The other one-third is based on how soon you finish the repair under the time limit. You will have one hour to do each repair. You will get a higher score if you work as quickly and as accurately as you can. You will install the parts on the pack in front of you. Everything will be supplied including tools, TMs, and parts. You have nothing to write. We will tell you your scores after you've finished the second test. We want you to do your best so that the test scores accurately represent your skill level. Do you have any questions? (Answer his questions before continuing.)*

Before we begin, I need to know:

- *How many times have you replaced the starter on a M60 since completing AIT?*
- *How long has it been since you last did this task? (Note: If the mechanic has not done the task since AIT, ask him how long that has been since he last did the repair at AIT or OJT.)*
- *How many times have you replaced the generator on the M60A1 tank?*
- *How long has it been since you last did this task? (Again, if the mechanic has no prior experience on this task, have him indicate the time since he last replaced a generator during training.)*

C-2: BRIEFING SCRIPT - TM KNOWLEDGE TEST (PART 1)

Now we will begin the starter (generator) test. I will first ask you some questions about the repair that will require you to use the TM. All the questions can be answered by referring to the TM. You are free to use the TM as much as you like (now and later in the test). This part of the test is not timed. It is worth 10 points. Do you have any questions? (If not, begin the test.)

Since positioning the starter (generator) is a two-man job, I'll act as your helper and will do whatever you ask for that step. After that you will work on your own.

C-3: BRIEFING SCRIPT - HANDS-ON PERFORMANCE TEST (PART 2)

Now you will take the main part of the test. It is worth 90 points. Laid out before you are the tools, replacement parts, and manuals that you need to replace the starter (generator). Since you will be scored on the order (sequence) in which you do the steps, feel free to use the TM to ensure that you are doing the steps in the right order.

Remember, time counts, so work quickly but as safely and accurately as possible. If you get stuck on a step, it is better to ask for help and lose a few accuracy points than to use up all of your time.

I will start timing when you give the signal.

APPENDIX D

SUMMARY DATA: MEAN CRITERION SCORES BY TEST AND JOB EXPOSURE CATEGORY

STARTER TEST

JE Category	No. Subjects	Overall Proficiency	Scoring Criteria: Time (Min.)	TM Know.	Sequence	Tool Select.	Tool Use	Quality Check
0	16	78.5	49.6	8.8	26.2	10.1	10.3	9.4
1	5	86.0	40.4	9.0	26.2	10.5	10.7	10.2
2	5	91.4	41.6	9.4	28.4	10.9	10.8	11.2
3	5	93.0	34.4	9.6	28.0	10.7	10.7	11.0
4	5	93.6	38.6	10.0	29.8	11.0	11.0	11.0
5	5	96.6	33.8	9.8	28.4	11.0	11.0	11.4
6	5	97.4	33.0	9.8	29.6	11.0	10.9	11.0
7	5	94.0	30.8	9.8	28.2	10.8	10.8	10.4
8	5	97.6	30.4	10.0	30.2	11.0	11.0	11.8
9+	12	92.8	37.0	9.5	27.3	10.8	10.8	10.7
Maximum Score Possible		100	—	10	31	11	11	12

GENERATOR TEST

JE Category	No. Subjects	Overall Proficiency	Scoring Criteria: Time (Min.)	TM Know.	Sequence	Tool Select.	Tool Use	Quality Check
0	12	89.4	29.7	8.0	25.7	10.3	11.2	2.5
1	6	93.8	27.2	8.7	26.8	11.5	11.3	2.5
2	5	97.0	21.2	10.0	27.2	11.8	12.0	3.0
3	6	97.3	23.2	9.8	28.2	11.7	11.8	2.8
4	5	96.6	19.6	9.8	28.0	11.4	11.5	3.0
5	5	99.6	18.2	9.8	30.0	12.0	11.9	3.0
6	5	97.6	19.2	9.8	28.2	11.7	11.7	3.0
7	6	95.3	20.7	9.3	26.5	11.9	11.9	2.5
8	7	96.0	19.4	9.7	27.1	11.6	11.8	2.6
9+	10	96.5	21.8	9.9	27.9	11.2	11.3	2.6
Maximum Score Possible		100	—	10	30	12	12	3

APPENDIX E
SUMMARY OF DATA POOLING AND STATISTICAL ANALYSES

The data were pooled in two ways to simplify presentation of the findings. First, the ten-level experimental design was reduced to six by combining subjects in adjacent pairs of JE categories between one and eight. This pooling did not change the overall pattern in the data, but it enhanced the stability of the means by ensuring that at least 10 subjects appeared in each category. Second, two scoring criteria, tool selection and tool use, were combined into a single measure. The obvious conceptual link between the two measures was reflected in the data, as subjects' scores on the two criteria were highly correlated ($r = +.80$).

Where appropriate, inferences regarding the relationship between JE and repair skill were based on statistical analyses of the data. To make the text more readable, the results of the statistical tests are included in this appendix. The choice of tests and the logic behind their use are described below.

Separate analyses, using the same statistical procedures, were made of the six maintenance proficiency measures for each of the two different repair tasks. The statistical significance of the overall relationship between JE and maintenance proficiency was determined by the F-statistic from an unbalanced analysis of variance. The strength of the relationship is indicated by the r^2 statistic, the proportion of variance in the proficiency measure explainable by JE.[1] Next, the magnitude of the increase in proficiency over the lower values of JE was statistically assessed by testing the significance of the linear trend component in a polynomial trend analysis.[2] Finally, the extent to which skill declined over the higher JE categories was inferred by examining the significance of the quadratic trend component.

The results of these analyses are given in the following tables.

[1] Hays, W. L. **Statistics for the social sciences.** New York: Holt, Rinehart, and Winston, 1973.

[2] Winer, B. J. **Statistical principles in experimental design** (2nd ed.). New York: McGraw-Hill, 1971.

MEASURE: OVERALL PROFICIENCY

Repair Task	Analysis	F-value	df[1]	r^2	p-level
Starter Installation	Overall Effect	11.02	5/62	.47[2]	.0001
	Linear Trend	28.62	1/62	.52[3]	.0001
	Quadratic Trend	19.81	1/62	.36[3]	.0001
Generator Installation	Overall Effect	13.57	5/61	.53[2]	.0001
	Linear Trend	27.62	1/61	.41[3]	.0001
	Quadratic Trend	29.10	1/61	.43[3]	.0001

MEASURE: TIME IN MINUTES

Repair Task	Analysis	F-value	df	r^2	p-level
Starter Installation	Overall Effect	11.39	5/62	.48	.0001
	Linear Trend	32.18	1/62	.56	.0001
	Quadratic Trend	18.23	1/62	.32	.0001
Generator Installation	Overall Effect	6.21	5/61	.34	.0001
	Linear Trend	17.05	1/61	.55	.0001
	Quadratic Trend	11.99	1/61	.39	.0001

MEASURE: TOTAL ACCURACY

Repair Task	Analysis	F-value	df	r^2	p-level
Starter Installation	Overall Effect	5.87	5/62	.32	.0002
	Linear Trend	10.11	1/62	.34	.0023
	Quadratic Trend	16.30	1/62	.56	.0002
Generator Installation	Overall Effect	7.27	5/61	.37	.0001
	Linear Trend	12.08	1/61	.33	.0009
	Quadratic Trend	18.41	1/61	.51	.0001

[1] Degrees of freedom for numerator, denominator, respectively.

[2] Proportion of total variance explained by the effect.

[3] Proportion of effect variance explained by the trend component.

MEASURE: TM KNOWLEDGE

Repair Task	Analysis	F-value	df	r^2	p-level
Starter Installation	Overall Effect	3.36	5/62	.21	.0095
	Linear Trend	7.88	1/62	.47	.0067
	Quadratic Trend	7.21	1/62	.43	.0093
Generator Installation	Overall Effect	10.86	5/61	.47	.0001
	Linear Trend	30.57	1/61	.56	.0001
	Quadratic Trend	14.11	1/61	.26	.0004

MEASURE: FOLLOWING SEQUENCE

Repair Task	Analysis	F-value	df	r^2	p-level
Starter Installation	Overall Effect	2.59	5/62	.17	.0338
	Linear Trend	3.29	1/62	.25	.0746
	Quadratic Trend	8.33	1/62	.64	.0054
Generator Installation	Overall Effect	2.98	5/61	.20	.0181
	Linear Trend	4.15	1/61	.28	.0460
	Quadratic Trend	5.31	1/61	.36	.0246

MEASURE: TOOL SELECTION/USE

Repair Task	Analysis	F-value	df	r^2	p-level
Starter Installation	Overall Effect	3.81	5/62	.23	.0046
	Linear Trend	7.47	1/62	.39	.0082
	Quadratic Trend	8.42	1/62	.44	.0051
Generator Installation	Overall Effect	4.57	5/61	.27	.0014
	Linear Trend	5.49	1/61	.24	.0224
	Quadratic Trend	13.02	1/61	.57	.0006

MEASURE: QUALITY CHECK

Repair Task	Analysis	F-value	df	r^2	p-level
Starter Installation	Overall Effect	3.48	5/62	.22	.0078
	Linear Trend	6.00	1/62	.34	.0171
	Quadratic Trend	8.41	1/62	.48	.0052
Generator Installation	Overall Effect[1]	0.95	5/61	.07	.4581

[1]Nonsignificant F-value invalidates further statistical testing of the trend components.